National Park Service
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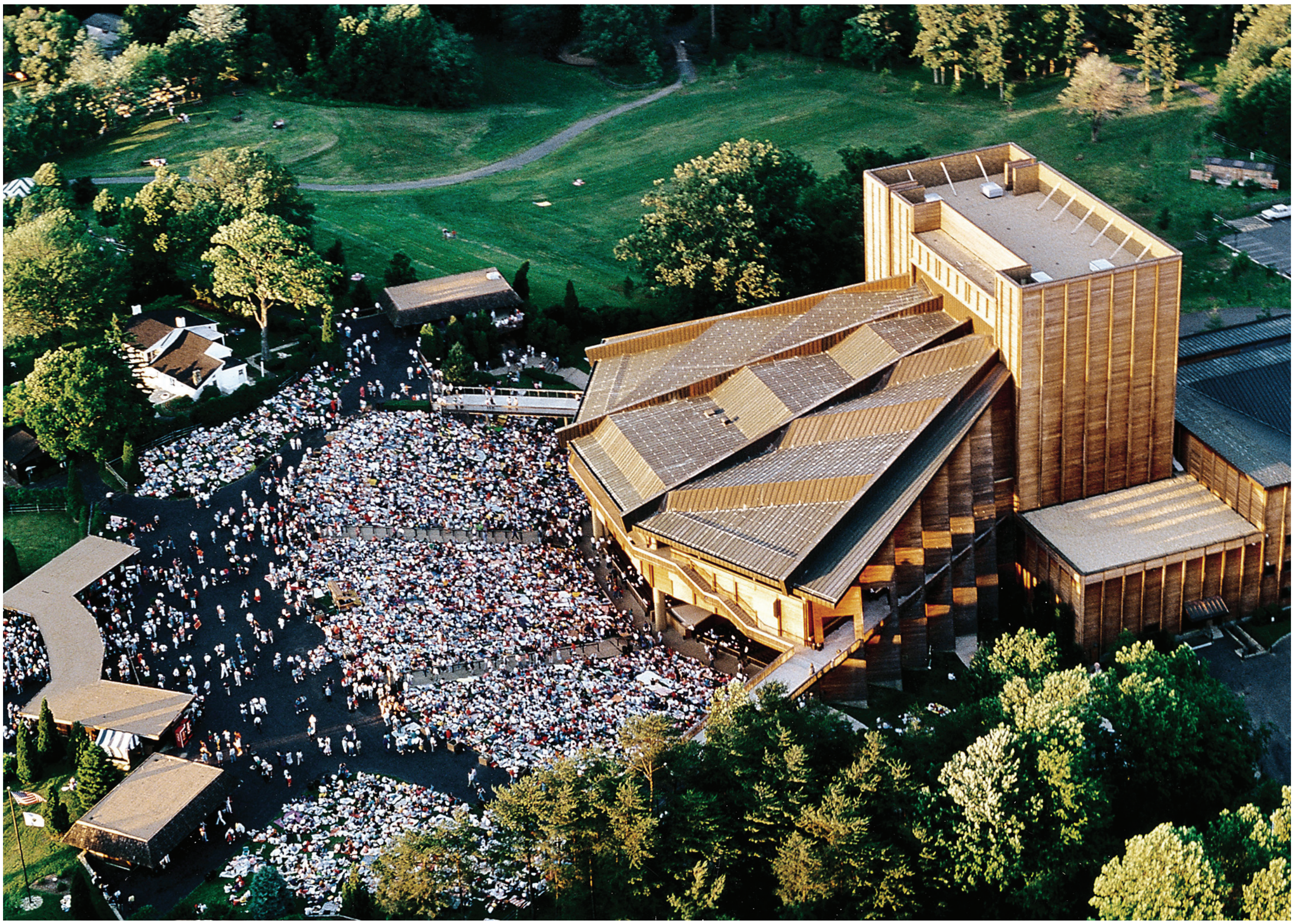
Natural Resource Program Center

Wolf Trap National Park for the Performing Arts

Geologic Resource Evaluation Report

Natural Resource Report NPS/NRPC/GRD/NRR—2008/041



THIS PAGE:
Concert at the Filene Center

ON THE COVER:
Aerial view of the Filene Center—Photo by, Robert Lewellyn

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Geologic Resources Division
Natural Resource Program Center
P.O. Box 25287
Denver, Colorado 80225

June 2008

U.S. Department of the Interior
Washington, D.C.

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Thornberry- Ehrlich, T. 2008. Wolf Trap National Park for the Performing Arts Geologic Resource Evaluation Report. Natural Resource Report NPS/NRPC/GRD/NRR—2008/041 . National Park Service, Denver, Colorado.

NPS D- 43, June 2008

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Executive Summary

This report accompanies the digital geologic map for Wolf Trap National Park for the Performing Arts in Virginia, which the Geologic Resources Division produced in collaboration with its partners. It contains information relevant to resource management and scientific research.

Wolf Trap National Park for the Performing Arts provides a venue for many significant cultural demonstrations and performances. The park also preserves vital natural habitat in the urban Washington, D.C., metropolitan area within the Potomac River watershed. It reflects a unique geologic history that spans from the ancient Precambrian through the formation of the Appalachian Mountains to the more recent Ice Age events and finally the modern day.

Geologic processes give rise to rock formations, hills and valleys, waterfalls and wetlands. These processes play a prominent role in the history of the entire Potomac River valley and Washington, D.C., sculpting a landscape that influences patterns of human use. The geology- history connection inspires wonder in visitors, and the interpretation and preservation of geologic resources enhances the visitor's experience.

The experience of the park begins with the geology, with the processes that established the groundwork from which today's environments, history, and scenery arise. Knowledge of the geologic resources can positively influence resource management decisions addressing a range of concerns, such as erosion, air and water quality, flooding, wildlife populations and invasive species, future scientific research projects, interpretive needs, future venue development, and urbanization.

Humans have significantly modified the landscape surrounding Wolf Trap and the geologic processes of the area. Urban developments threaten this dynamic ecosystem, which is capable of noticeable change within a human life span. The following features, issues, and processes have geological importance and a high level of management significance within the park:

- Sediment Load, Channel Storage and Morphology

  Erosion at Wolf Trap increases the sediment carried by park streams. Sediment loads and distribution affect aquatic and riparian ecosystems. Sediment loading can change channel morphology and increase the frequency of overbank flooding. Fine- grained sediments can transport contaminants in a water system. Sediment loading follows a seasonal cycle and may warrant further investigation.

- Recreational Demands

  Wolf Trap National Park for the Performing Arts is a popular haven and venue in the densely populated Washington, D.C., area. Visitor use, from hiking to picnicking, places increasing demands on the protected areas within the park. Understanding the response of the landscape to visitor overuse is a resource management concern, as is visitor safety, especially along stream banks.

- Soil Erosion

  Soils provide a critical link between geology and biology. Soils at Wolf Trap have been disturbed and altered by agriculture, development, urbanization of the surrounding area, and erosion. The Soil Resource Inventory (SRI) Program of the NPS Geologic Resources Division is equivalent to the Geologic Resource Evaluation Program but focused on soils rather than geology. SRI maps and databases for Wolf Trap National Park for the Performing Arts are slated for completion in 2009.

Additional issues including general geologic research, water quality and quantity, and a range of other potential action items have been identified as management concerns for Wolf Trap National Park for the Performing Arts. It may be possible to link interpretive needs with land- use planning and visitor use in the park. Along with a detailed geologic map and a road or trail log, a guidebook connecting Wolf Trap National Park for the Performing Arts to the other parks in the Central Appalachian region would enhance a visitor's appreciation of the region's rich geologic history and the dynamic processes that created the natural landscape and affected human history showcased in the region.

Introduction

The following section briefly describes the National Park Service Geologic Resource Evaluation Program and the regional geologic setting of Wolf Trap National Park for the Performing Arts.

Purpose of the Geologic Resource Evaluation Program

The Geologic Resource Evaluation (GRE) Program is one of 12 inventories funded under the NPS Natural Resource Challenge designed to enhance baseline information available to park managers. The program carries out the geologic component of the inventory effort from the development of digital geologic maps to providing park staff with a geologic report tailored to a park's specific geologic resource issues. The Geologic Resources Division of the Natural Resource Program Center administers this program. The GRE team relies heavily on partnerships with the U.S. Geological Survey, Colorado State University, state surveys, and others in developing GRE products.

The goal of the GRE Program is to increase understanding of the geologic processes at work in parks and provide sound geologic information for use in park decision making. Sound park stewardship relies on understanding natural resources and their role in the ecosystem. Geology is the foundation of park ecosystems. The compilation and use of natural resource information by park managers is called for in section 204 of the National Parks Omnibus Management Act of 1998 and in NPS- 75, Natural Resources Inventory and Monitoring Guideline.

To realize this goal, the GRE team is systematically working towards providing each of the identified 270 natural area parks with a geologic scoping meeting, a digital geologic map, and a geologic report. These products support the stewardship of park resources and are designed for non- geoscientists. During scoping meetings the GRE team brings together park staff and geologic experts to review available geologic maps and discuss specific geologic issues, features, and processes.

The GRE mapping team converts the geologic maps identified for park use at the scoping meeting into digital geologic data in accordance with their innovative Geographic Information Systems (GIS) Data Model. These digital data sets bring an exciting interactive dimension to traditional paper maps by providing geologic data for use in park GIS and facilitating the incorporation of geologic considerations into a wide range of resource management applications. The newest maps come complete with interactive help files. As a companion to the digital geologic maps, the GRE team prepares a park- specific geologic report that aids in use of the maps and provides park managers with an overview of park geology and geologic resource management issues.

For additional information regarding the content of this report and up to date GRE contact information please refer to the Geologic Resource Evaluation Web site (http://www2.nature.nps.gov/geology/inventory/).

Geologic Setting

Wolf Trap National Park for the Performing Arts is located in Virginia about 13 km (8 miles) west of Washington, D.C. in an area referred to herein as the National Capital Region (fig. 1). The park began as a gift from Catherine Filene Shouse. Formerly known as Wolf Trap Farm Park (October 15, 1966, by Public Law 89- 671 89th Congress, S. 3423), it was designated the first national park for the performing arts on August 21, 2002. This park offers a 130- acre respite in the Washington, D.C., metro area. In addition to its rich historical context, the park provides a natural sanctuary for native bird, plant, and animal species. The park attracted 485,689 visitors in 2006.

This historic park protects a portion of the Piedmont Physiographic Province of the Appalachian Highlands, one of several geologically significant physiographic provinces in the eastern United States (fig. 2). Varied hydrological influences acting on the underlying geology have built a complex topography at Wolf Trap. The landscape consists of wooded rolling hills, a stream valley (Wolf Trap Run and its tributaries, Courthouse Branch and a smaller unnamed waterway), and flat to gently sloping areas. The overall elevation range is about 30 m (100 ft). The highest hills in the park are in the southeast corner; the lowest points are in the flood plain in the northwest corner. These topographic and elevation differences in addition to seasonal flooding support a diversity of habitats ranging from year- round wetlands to dry, steep, forested slopes.

The following are general descriptions of several of the different physiographic provinces from the Atlantic Coastal Plain to the Appalachian Mountains (fig. 2). This information is relevant to understanding the geologic history of Wolf Trap National Park for the Performing Arts.

Atlantic Coastal Plain Province

The Atlantic Coastal Plain province is primarily flat terrain with elevations ranging from sea level to about 100 m (300 ft) in Virginia. Located along the coast and in places stretching inland, it extends from New York to Mexico. Sediments eroding from the Appalachian highlands to the west were deposited intermittently in a wedge- shaped sequence during periods of higher sea level over the past 100 million years. The sediments are more than 2,400 m (7,900 ft) thick at the Atlantic coast. The deposits were reworked by fluctuating sea levels and the continual erosive action of waves along the coastline. The province continues off shore as the submerged continental shelf for another 120 km (75 miles) to the east.

In northern Virginia the Coastal Plain province stretches from the Fall Line east to the Chesapeake Bay and Atlantic Ocean. Coastal Plain surficial materials are commonly well drained sandy or sandy- loam soils. Large streams and rivers in the Coastal Plain province, including the James, York, Rappahannock, and Potomac Rivers, continue to transport sediment and to extend the Coastal Plain eastward.

Piedmont Province

The "Fall Line" or "Fall Zone" marks a transitional zone where the softer, less consolidated sedimentary rock of the Atlantic Coastal Plain to the east intersects the harder, more resilient metamorphic rock to the west, forming a series of ridges, waterfalls, and rapids (fig. 3). This zone covers more than 27 km (17 miles) of the Potomac River from Little Falls Dam, near Washington, D.C., west to Seneca, Maryland. Examples of this transition are present in the Potomac Gorge of the Chesapeake and Ohio Canal National Historic Park and at Great Falls Park. The Piedmont Physiographic Province encompasses the Fall Line westward to the Blue Ridge Mountains.

The eastward- sloping Piedmont formed through a combination of folding, faulting, metamorphism, uplift, and erosion. The result was a landscape of gently rolling hills in the east starting at 60 m (200 ft) in elevation. The hills become gradually steeper toward the western edge of the province, where they reach 300 m (1,000 ft) above sea level. The Piedmont is composed of hard, crystalline igneous and metamorphic rocks including schists, phyllites, slates, gneisses, and gabbros. Soils in the Piedmont are highly weathered and generally well drained.

A series of Triassic age extensional basins occurs in the Piedmont. Normal faulting during crustal extension formed these basins. This faulting created down-dropped troughs (grabens) that rapidly filled with roughly horizontal layers of sediment. Examples include the Frederick valley in Maryland and the Culpeper valley of Northern Virginia.

Blue Ridge Province

The Blue Ridge province is located along the eastern edge of the Appalachian Mountains. The highest elevations in the Appalachian Mountains occur in this province in the Great Smoky Mountains of North Carolina and Tennessee. Precambrian and Paleozoic igneous, sedimentary, and metamorphic rocks were uplifted during several orogenic events forming the steep, rugged terrain.

Resistant Cambrian age quartzites form the Blue Ridge, Bull Run Mountain, South Mountain, and Hogback Ridge in Virginia (Nickelsen 1956). The elongate belt of the Blue Ridge stretches from Pennsylvania to Georgia. South Mountain and Catoctin Mountain, both anticlines, are two examples of the pervasive folding in the Blue Ridge province.

Eroding streams have narrowed the northern section of the Blue Ridge Mountains into a thin band of steep ridges, with heights of approximately 1,200 m (3,937 ft). The Blue Ridge province is typified by steep terrain covered by thin, shallow soils that allow rapid runoff contributing to low groundwater recharge rates.

Valley and Ridge Province

Long, parallel ridges separated by valleys characterize the landscape of the Valley and Ridge Physiographic Province. The valleys formed where resistant sandstone ridges border more easily eroded shale and carbonate formations. The province contains strongly folded and faulted sedimentary rocks in western Maryland.

Certain areas dominated by carbonate formations exhibit karst topography dotted by sinkholes, caves, and caverns. The karstic eastern portion of the Valley and Ridge province is part of the Great Valley (Shenandoah Valley). The Valley and Ridge province connects to the Piedmont province by streams that cut through the Blue Ridge Mountains.

Geology and History at Wolf Trap National Park for the Performing Arts

The entire Potomac River valley is rich in archeological resources that document 10,000 years of human habitation. The geology of the area has always attracted people to its vast natural resources. Ancient people came here to use the unique stone, including flint and chert for tools, establishing base camps and processing sites in several locations. The Potomac and its tributaries provided Native Americans (Piscataway Tribe) with a concentration of fish, game, and numerous plant species, as well as wood, stone, shell, and bone necessary for tools and trade.

Geology also played a vital role in early European settlement success. In the area around Washington, D.C., rivers supported local trade, developed fertile flood plains, and provided resources for the inhabitants. The geology influenced or even dictated placement of river crossings and fords. Likewise, early railroads and roads often followed the trends of natural geologic features. Educating the public about interconnections between history and science, and building a deeper understanding of the landscape, requires an explanation of the role of geologic controls during settlement and human history.

A major National Park Service goal is to preserve the historical context of the Wolf Trap area (figs. 4, 5). Historic buildings and the landscape around them are to be preserved and restored, including the pastoral Shouse farm landscape at Wolf Trap.

There are several management challenges in maintaining this landscape, because it often means resisting natural geologic changes. Geologic slope processes such as chemical weathering, landslides, slumps, and slope creep are constantly changing the landscape at the park. Runoff erodes sediment from any open areas and carries it down streams and gullies. Erosion naturally diminishes higher areas and fills in the lower areas, distorting the historical context of the landscape.

Issues also arise between cultural and natural resource management. For example, a proposal for restoration of an historic building or the development of new performance areas may include removing surrounding natural resources or planting exotic species. Streams and rivers are often altered to preserve fishing habitat and to protect trails, buildings, and stream banks from being undercut. These activities attempt to reverse natural geologic changes.

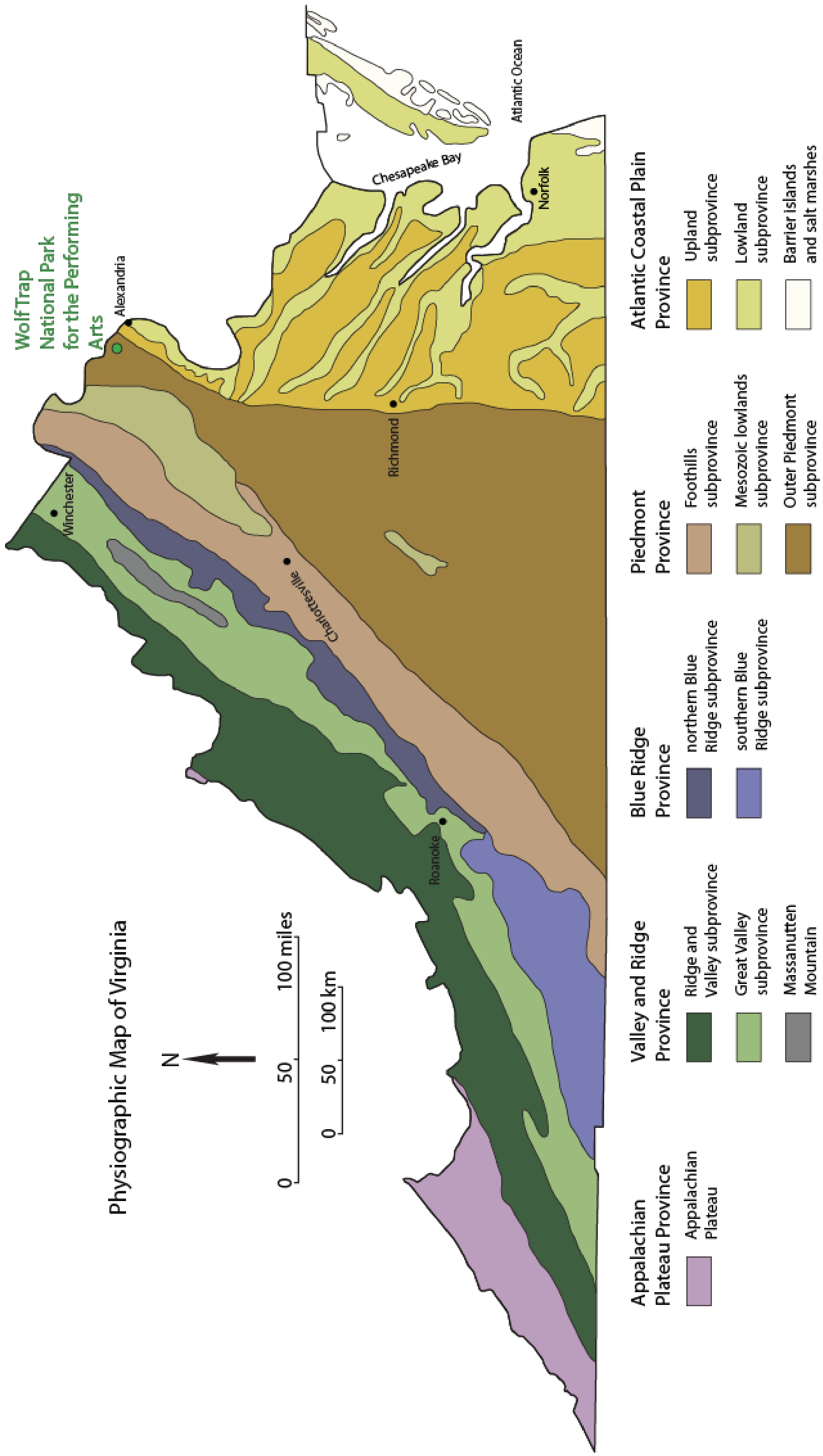

Figure 2: Location of Wolf Trap National Park for the Performing Arts relative to the physiographic provinces of Virginia. Modified from Bailey (1999).

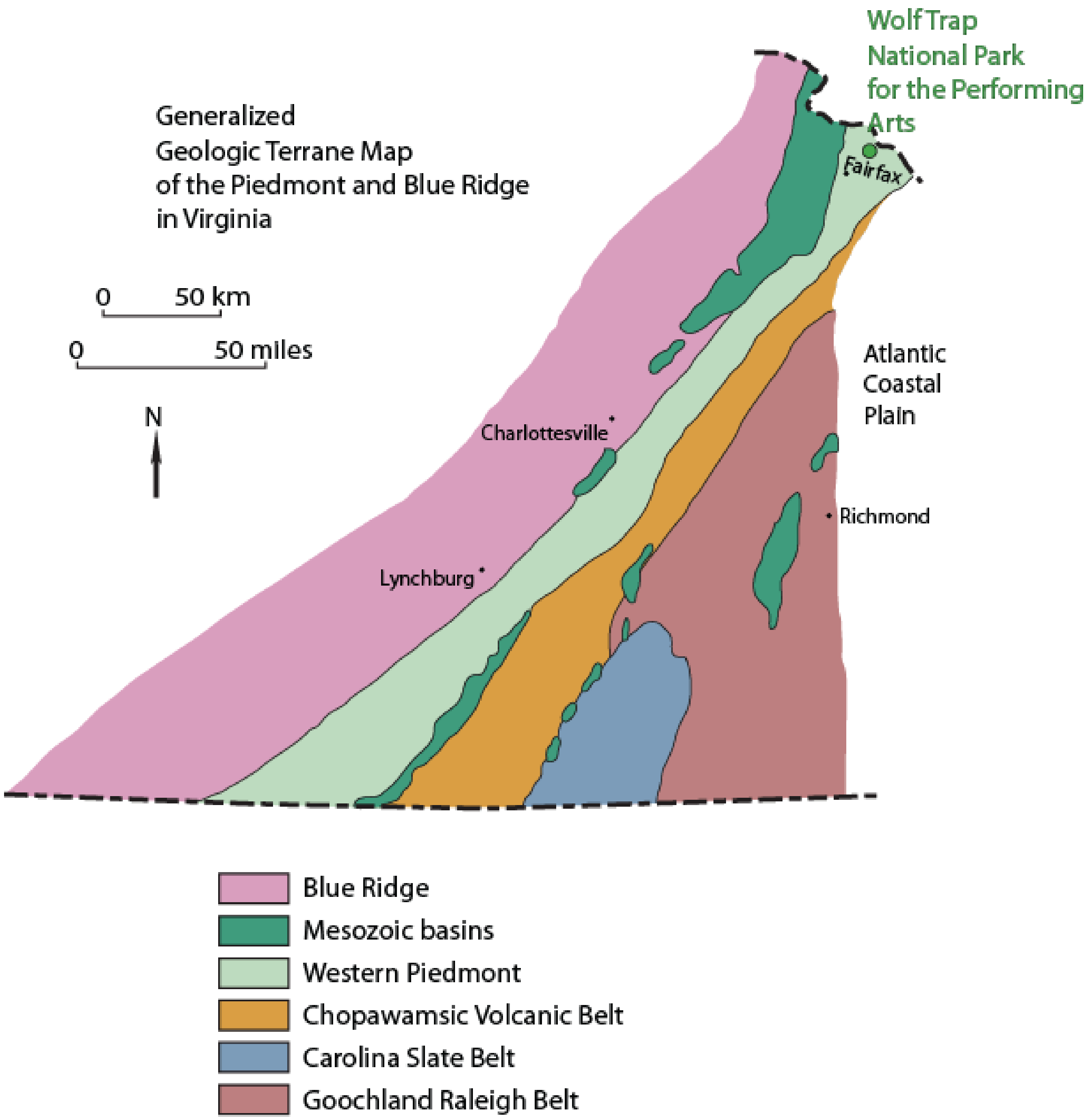

Figure 3: Geologic map of the Piedmont and Blue Ridge in central Virginia. Heavy dashed line indicates state boundaries. Modified from Bailey (1999).

Figure 4: The original historic farmhouse at Wolf Trap. Photograph courtesy of the National Park Service.

Figure 5: Historic Barn Road. Photograph courtesy of the National Park Service.

Geologic Issues

A Geologic Resource Evaluation scoping session was held for Wolf Trap National Park for the Performing Arts on April 30–May 2, 2001, to discuss geologic resources, address the status of geologic mapping, and assess resource management issues and needs. In addition two other meetings–one held on July 9–11, 2002 focused on monitoring and the other held on May 20, 2002 focused on the influence of geologic processes and humans–are referenced in the following section. This section synthesizes results of these meetings, with emphasis on those issues that may require attention from resource managers.

Sediment Load, Channel Storage, and Morphology

Erosion of the landscape within the Difficult Run watershed leads to increases in sediment carried by streams flowing through the park. Sediment loads and distribution affect aquatic and riparian ecosystems. Sediment loading can result in changes to channel morphology and increase the frequency of overbank-flooding. One of the most important functions of a riparian zone is the ability of vegetation to improve water quality by trapping sediments containing contaminants from disturbed areas. However, little data exists quantifying the impacts of sediment deposition from anthropogenic disturbances on processes within these ecosystems. A study conducted in Georgia focused on disturbed areas generating a range of sedimentation levels in riparian zones near small ephemeral streams. The results of this study suggest that fine root dynamics may be affected by sediment deposition rates commonly occurring in riparian areas near disturbed lands, and that the water filtration function performed by these ecosystems may also be affected (Cavalcanti and Lockaby 2005).

Suspended sediment load is a resource management concern, as the sediment can contaminate drinking water sources, and increase concentrations of toxic chemicals formerly trapped in stream bottom sediments. However, fine- grained sediments are also vital in the overall fluvial transport of contaminants in a water system. Channel storage of fine sediment (and the contaminants contained therein) follows a seasonal cycle. This cycle is subject to hydrologic variability with increased availability during the high stands of spring and decreased availability during the low stands in autumn. Fine- grained sediments do not travel downstream in a single pulse but are often resuspended bottom material (Miller et al. 1984). This intermittent transport of contaminants and fine- grained sediment enlarges the affected area.

Recreational Demands

The National Park Service is to protect park resources for the enjoyment of current and future generations of visitors. The inherent purpose of Wolf Trap is to act as a natural sanctuary (woodlands), an outdoor museum of pastoral farm use, and a venue for artistic performances. This introduces many visitors to the small natural area of the park. The park promotes activities that do not damage the park's resources or endanger visitors.

The park receives many visitors every year. In 2006, as many as 485,689 people entered the park to recreate. Approximately 24 acres (or 19%) of the parklands are developed as paved roads, trails, and structures, including the park administrative buildings and the Filene Center (accommodates 7,028 people) (NPS 2005). Visitors are placing increasing demands on the resources of the park, and management concerns vary from trail erosion, water quality, and wetland health to riverbank erosion.

In numerous places throughout the park, unconsolidated soils and sediments are exposed on a slope (gradient as high as 30%) with sparse vegetation. The slope angle and lack of stabilizing vegetation renders the soil materials highly susceptible to erosion and degradation. Park management attempts to concentrate the impacts of recreation with designated trails and picnic areas. Continued use in prohibited or nondesignated areas places delicate ecosystems at risk for damage from increased impact and contamination from waste.

Inventory, monitoring, and research suggestions for recreational demands include:

- Include inventory and monitoring in future resource management plans that would further identify human impact to geomorphologic or geohydrologic processes within the park,
- Design wayside exhibits to encourage responsible use of park resources, and
- Plant stabilizing native vegetation along slopes at risk for slumping and erosion.

Water Issues

In the moist eastern climate of the National Capital Region, water seems present everywhere in streams, rivers, runoff, springs, and groundwater wells. Annual precipitation in Washington, D.C., averages ~100 cm (39.35 inches) per year, and almost half of the rain falls in the summer months during short intense storms. Water resources at the park are under constant threat of overuse and contamination because of surrounding development.

The park's primary permanent water resource is Wolf Trap Creek. Two small tributaries, Courthouse Branch and an unnamed watercourse, are also present within the park. Wolf Trap Creek is a part of the Difficult Run watershed. In addition, a 2- acre farm pond (habitat for a variety of amphibians, and migrating and resident birds) and a permanent spring are components of the park's hydrologic system.

Major threats to water quality in the Wolf Trap area include (1) sediment, nutrients, heavy metals, and organic chemicals in urban and agricultural runoff, (2) bacteria, nutrients, and heavy metals from household sewage effluent discharges, and (3) organic chemicals, heavy metals, and high biochemical oxygen demand from effluents generated by industries and developed areas. Impacts from operations within the park proper are suspected, but have yet to be measured (NPS 2005).

Threats to ground water quality include the influx of fertilizers, pesticides, herbicides, manure, septic effluent, and road salt, are concentrated in urban areas surrounding the park. Acid rain and snow are known to cause acidification of streams and rivers in the area (http://www.wilderness.org/Library/Documents/upload/Potomac- River- Watershed- Facts.pdf, accessed March 28, 2008).

The hydrogeologic system is impacted by increased surface runoff from impervious surfaces such as parking lots, roads, and building footprints. Likewise, impervious surfaces decrease the base flow of streams by preventing infiltration into the aquifer. The difference between base and peak streamflows typically increases as a consequence of development in the absence of mitigation measures such as detention ponds. Sedimentation also increases due to land clearing activities for development. Water temperature increases because of the insulating nature of impervious surfaces. (Runoff from a parking lot on a hot July day is at a much higher temperature than runoff from a grassy slope.)

The movement of nutrients and contaminants through the hydrogeologic system can be modeled by monitoring the composition of system inputs, such as rainfall, and outputs, such as streamflow. Other input sources include wind, surface runoff, groundwater transport, sewage outfalls, landfills, and fill dirt.

Streams in effect integrate the surface runoff and groundwater flow of their watersheds. Thus, they provide a cumulative measure of the status of the watershed's hydrologic system. Consistent measurement of these parameters is crucial to establishing baselines for comparison.

Soil Erosion

Soils provide an important link between geology and biology in the National Capital Region. Soils support life and are derived from underlying bedrock, augmented by transported sediments and nutrients as well as organic matter. The geology, or the rock types, from which the soils are derived, influences soil chemistry. Regional soils developed from a variety of basement rocks including limestone, greenstone, red shale, and quartzite.

Since Colonial time (~1650s–1700), the National Capital Region has been cleared for farming and in the process stripped of much soil. The result has been increased sediment input into regional waterways. A large part of this sediment is permanently lost, unless manmade structures, or beaver dams are able to slow erosion and runoff.

The Soil Resources Inventory (SRI) Program of the NPS Geologic Resources Division is working with the Natural Resources Conservation Service (NRCS) to complete a soil survey for Wolf Trap National Park for the Performing Arts. This project is underway and projected for completion in 2009. The SRI Program provides user-friendly products to park managers to facilitate effective resource management, as well as baseline information on soil resources for the Vital Signs Monitoring Program. Soil resource inventories equip parks with maps showing the locations and extent of soils; data about the physical, chemical, and biological properties of those soils, as well as information regarding potential uses and limitations of each kind of soil type. The products also can be used for park interpretive programs and to identify emerging Soil Program needs.

General Geology

A meeting held in August 2002 to assess geologic monitoring objectives for the National Capital Region Vital Signs Network (including Wolf Trap National Park for the Performing Arts) identified the following geologic resource components: soils and bedrock, ground water, bare ground and exposed rock, karst, surface water, coastal areas, and riparian areas and wetlands. Resource management could benefit from consideration of these components and their contributions to the entire ecosystem.

Stresses to these components include nutrient and chemical contamination, sediment erosion and deposition, shoreline changes, and geo- hazards. These stressors are potential areas for ecosystem monitoring. Development, acid rain, atmospheric deposition, climate change, abandoned mines and wells, and visitor use are thought to be primary sources of stress to the natural resources at Wolf Trap National Park for the Performing Arts.

Digital geologic data facilitates science based decision making for resource managers by allowing integration with other spatial data in a GIS. Potential uses of digital geologic data include:

1. identification and description of critical habitats for rare and endangered species;
2. hazard assessments for events such as floods, rockfalls, or slumps;

3. creation of interpretive programs to illustrate the evolution of the landscape and Earth history of the park in lay- person terms;
4. identifying the location of sources of aggregate and building stone for historical reconstruction;
5. determining environmental impacts for any new construction;
6. inventory of natural features such as springs, cliffs, marker beds, fossil localities, and caves;
7. characterizing land use; and
8. defining ecological zones and implementing conservation plans (Southworth and Denenny 2003).

Inventory, monitoring, and research suggestions for general geology include:

- Promote research investigating the processes active along fault zones in the Piedmont.
- Consider performing geochemical studies to understand the path of nutrients through various bedrock lithologies.
- Use historical photographs, descriptions, and surveys to determine the topography prior to human impact.
- Research the surficial geologic story at the park and develop an interpretive program that relates the current landscape, ecosystem, history, and biology to the geology.
- Document locations of swelling clays and assess any influence they may have on park resources, including roadways, trails, and buildings.
- Compile baseline geologic data; develop a geologic bibliography; create a database of geologic maps; research geologic studies and reports; develop a geologic site bulletin or brochure; and, collect and display geologic data using GIS and GPS.
- Promote interpretive exhibits to educate the public about the tectonic history of the eastern United States.

Map Unit Properties

This section identifies characteristics of map units that appear on the Geologic Resource Evaluation digital geologic map of Wolf Trap National Park for the Performing Arts. The accompanying table is highly generalized and is provided for background purposes only. Ground- disturbing activities should not be permitted or denied on the basis of information in this table. More detailed map unit descriptions can be found in the help files that accompany the digital geologic map or by contacting the National Park Service Geologic Resources Division.

The geologic bedrock map units within Wolf Trap National Park for the Performing Arts include Precambrian to lower Paleozoic metasedimentary and metaigneous rocks associated with a suture between the Piedmont and Blue Ridge physiographic provinces (Bailey 1999). The sedimentary and volcanic rocks that were thrust along faults during deposition in a Late Proterozoic to Early Cambrian oceanic trench setting mixed with unconsolidated sediments to form a mélange, or mixture, of rocks.

This mélange was then metamorphosed into deformed crystalline rocks that now make up the geologic units shown on the map of the park. Locally these units include polydeformed schists, gneisses, phyllites, and metagraywackes of the Peters Creek Schist (mapped as the Mather Gorge Formation in nearby Great Falls Park by Southworth et al. 2000b). The Peters Creek Schist was thrust over the younger, mixed origin (mélange) phyllonitic rocks of the Sykesville Formation along the Plummers Island thrust fault (Southworth et al. 2001). Nearby igneous intrusive rocks include granites, quartz monzonites, and granodiorites (VDMR 1993; Southworth et al. 2000b).

Elsewhere, artificial fill and local limonite- cemented alluvial clay, silt, sand, and lowermost colluvial gravel units vary in age from middle Miocene to present (Maryland Geological Survey 1968; Southworth et al. 2001). Prominent among these later sediments are terrace deposits perched on bedrock ledges carved by the Potomac River (Southworth et al. 2000a; Southworth et al. 2001). The oldest of these deposits is dated at 10 thousand years ago to 5 Ma northeast of Wolf Trap at Glade Hill. Flood- plain alluvium including sand, gravel, silt, and clay makes up the most recent map units at Wolf Trap.

The geologic units in the following table and their geologic features and properties correspond to the units found in the accompanying digital geologic data. Source data for the GRE digital geologic map are from:

Southworth, S. and D. Denenny. 2006. *Geologic Map of the National Parks in the National Capital Region, Washington D.C., Virginia, Maryland and West Virginia*. Scale 1:24,000. U.S. Geological Survey. Open-File Report: OF 2005- 1331.

The following pages present a tabular view of the stratigraphic column and an itemized list of features for each map unit. This sheet includes properties specific to each unit present in the stratigraphic column, including map symbol, name, description, resistance to erosion, suitability for development, hazards, paleontologic resources, cultural and mineral resources, karst issues, habitat, recreational use, and significance.

Geologic History

This section describes the rocks and unconsolidated deposits that appear on the digital geologic map of Wolf Trap National Park for the Performing Arts, the environment in which those units were deposited, and the timing of geologic events that created the present landscape.

Wolf Trap National Park for the Performing Arts is located at the narrow north end of the western Piedmont Physiographic Province in northern Virginia. This location is near the Fall Line (between the Piedmont and Atlantic Coastal Plain) to the east, and the Blue Ridge province to the west. As such, it contains features that are innately tied to the long geologic history of the Appalachian Mountains and the evolution of the eastern coast of the North American continent.

The rocks underlying Wolf Trap include lower Paleozoic metasedimentary and meta- igneous rocks associated with the suture zone between the Blue Ridge and the Piedmont (Bailey 1999). A regional perspective of the geologic history is presented here to situate the landscape and geology of the park within its larger region.

The recorded history of the Appalachian Mountains begins in the Proterozoic (figs. 6, 7). In the mid-Proterozoic, during the Grenville Orogeny, a supercontinent formed composed of most of the continental crust in existence at that time, including the crust of North America and Africa. Sedimentation, deformation, plutonism (igneous intrusions), and volcanism are manifested in the metamorphic granites and gneisses in the core of the modern Blue Ridge Mountains (Harris et al. 1997).

The sediments that formed these rocks were deposited over a period of 100 million years and are more than 1 billion years old, making the rocks among the oldest known from this region. Following uplift, they were exposed to erosive forces for hundreds of millions of years. Their subdued surface forms a basement upon which all other rocks of the Appalachians formed (Southworth et al. 2001).

The late Proterozoic, roughly 800–600 million years ago, brought a tensional, rifting tectonic setting to the area. The crustal extension created fissures through which massive volumes of basaltic magma were extruded. This volcanic extrusion lasted tens of millions of years and alternated between flood basalt flows and ash falls. The metamorphosed remnants of these igneous rocks are found in the Catoctin Greenstones of Shenandoah National Park, and Catoctin Mountain Park, west of Wolf Trap.

Because of the tensional tectonic forces, the supercontinent broke up, and a basin formed that eventually became the Iapetus Ocean. This basin subsided and accumulated much of the sediment that would eventually form the Appalachian Mountains. Thick layers of sand, silt, and mud deposited in the Iapetus Ocean became the Sykesville and Mather Gorge Formations after regional deformation and metamorphism. Large blocks of eroded fragments from the Grenville highlands mixed with these sediments (Southworth et al. 2000b).

Some of the sediments were deposited as alluvial fans, large submarine landslides, and turbidites, which today preserve the dramatic features of their emplacement. These early sediments are exposed on Catoctin Mountain, Short Hill–South Mountain, Blue Ridge–Elk Ridge, and in areas to the west of the park as the Chilhowee Group (Loudoun Formation, Weverton Formation, Harpers Formation, and Antietam Formation) (Southworth et al. 2001).

Associated with the shallow- marine setting along the eastern continental margin of the Iapetus Ocean were large deposits of sand, silt, and mud in near- shore, deltaic, barrier island, and tidal flat environments. Some of these are present in the Chilhowee Group in central Maryland, including the Harpers and Antietam Formations (Schwab 1970; Kauffman and Frey 1979; Simpson 1991).

In addition, huge masses of carbonate rocks, such as the Cambrian age Tomstown Dolomite and Frederick Limestone, as well as the Upper Cambrian to Lower Ordovician Grove Limestone, were deposited on top of the Chilhowee Group. They formed a grand platform, thickening to the east, that persisted during the Cambrian and Ordovician Periods (545–480 Ma) and form the floors of Frederick and Hagerstown valleys (Means 1995).

Somewhat later, 540, 470, and 360 million years ago, igneous granodiorite, pegmatite, and lamprophyre, respectively, intruded the sedimentary rocks including those of the Mather Gorge Formation. During several episodes of mountain building and continental collision (discussed below), the entire pile of sediments, intrusives, and basalts was deformed and metamorphosed into schist, gneiss, marble, slate, and migmatite (Southworth et al. 2000a).

Taconic Orogeny

From Early Cambrian through Early Ordovician time, orogenic activity along the eastern margin of the continent began again. The Taconic Orogeny (~440–420 Ma in the central Appalachians) was a volcanic arc–continent convergence. Oceanic crust and the volcanic arc from the Iapetus basin were thrust onto the east edge of the North American continent.

The Taconic Orogeny involved the closing of the ocean, subduction of oceanic crust, the creation of volcanic arcs, and the uplift of continental crust (Means 1995). Initial metamorphism of the igneous and sedimentary rocks of the Sykesville and Mather Gorge Formations into schists, gneisses, migmatites, and phyllites occurred during this orogenic event.

In response to the overriding plate thrusting westward onto the continental margin of North America, the crust bowed downwards creating a deep basin that filled with mud and sand eroded from the highlands to the east (Harris et al. 1997). This so- called Appalachian basin centered on what is now West Virginia. Infilling sediments covered the grand carbonate platform and are recorded today by the shale of the Ordovician Martinsburg Formation (Southworth et al. 2001).

During the Late Ordovician, the oceanic sediments of the shrinking Iapetus Ocean were thrust westward onto other deepwater sediments of the western Piedmont. This occurred along the Pleasant Grove fault and other local faults such as the Plummers Island fault. Sediments forming sandstones, shales, siltstones, quartzites, and limestones were then deposited in the shallow- marine to deltaic environment of the Appalachian basin. These rocks, now metamorphosed, currently underlie the Valley and Ridge province west of Wolf Trap (Fisher 1976).

Shallow- marine to fluvial sedimentation continued for about 200 million years during the Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian Periods. The thick piles of sediments were derived from the newly formed highlands during the Taconian (Ordovician) and Acadian (Devonian) orogenies.

Acadian Orogeny

The Acadian Orogeny (~360 Ma) continued the mountain building of the Taconic Orogeny as the African continent approached North America (Harris et al. 1997). Similar to the preceding Taconic Orogeny, the Acadian event involved land mass collision, mountain building, and regional metamorphism (Means 1995). This event was focused farther north than central Maryland–Virginia.

Alleghenian Orogeny

Following the Acadian orogenic event, the proto- Atlantic Iapetus Ocean closed completely during the late Paleozoic, as the North American and African continents collided. This collision formed the Pangaea supercontinent and the predecessor of Appalachian mountain belt we see today. The mountain- building episode, termed the Alleghenian Orogeny (~325–265 Ma), is the last major orogeny of Appalachian evolution (Means 1995).

The rocks were deformed by folding and faulting to produce the Sugarloaf Mountain anticlinorium and the Frederick valley synclinorium in the western Piedmont, the Blue Ridge–South Mountain anticlinorium, and the numerous folds of the Valley and Ridge province (Southworth et al. 2001).

During this orogeny, rocks of the Great Valley, Blue Ridge, and Piedmont provinces were transported as a massive block (Blue Ridge–Piedmont thrust sheet) westward onto younger rocks of the Valley and Ridge along the North Mountain fault. The amount of compression was extreme: estimates of 20%–50% shortening translate into 125–350 km (78–217 miles) of transport (Harris et al. 1997).

Deformed rocks in the eastern Piedmont were also folded and faulted and existing thrust faults were reactivated as both strike- slip and thrust faults during the Alleghenian orogenic events (Southworth et al. 2001). Paleoelevations of the Allegheny Mountains are estimated at approximately 6,000 m (20,000 ft) (analogous to the modern- day Himalayas). Erosion has beveled these mountains to elevations less than 600 m (2,000 ft) west of Wolf Trap National Park for the Performing Arts (Means 1995).

Triassic Extension to the Present

Following the Alleghenian Orogeny, during the Late Triassic (about 230 to 200 Ma), a period of rifting began as the deformed rocks of the joined continents began to break apart. The supercontinent Pangaea was segmented into roughly the continents that persist today. This episode of rifting or crustal fracturing initiated the formation of the current Atlantic Ocean and caused many block- fault basins to develop with accompanying volcanism (Harris et al. 1997; Southworth et al. 2001).

The Newark Basin system is a large component of this tectonic setting. Large alluvial fans and streams carried debris shed from the uplifted Blue Ridge and Piedmont provinces. These sediments consolidated as nonmarine shales and sandstones in fault- created troughs (grabens) such as the Frederick valley in central Maryland and the Culpeper basin in the western Piedmont of central Virginia. Many of these rifted openings became lacustrine basins accumulating thick deposits of siltstone and sandstone.

Large faults formed the western boundaries of the basins and provided an escarpment that was quickly covered with eroded debris. Igneous rocks intruded into the new sandstone and shale strata as subhorizontal sheets, or sills, and near- vertical dikes that extend beyond the basins into adjacent rocks. After these molten igneous rocks were emplaced, at approximately 200 Ma, the region underwent a period of slow uplift and erosion.

The uplift was in response to isostatic adjustments within the crust, which forced the continental crust upwards and exposed it to erosion.

Thick deposits of unconsolidated gravel, sand, and silt were shed from the eroding mountains. These were deposited at the base of the mountains as alluvial fans and spread eastward to be part of the Atlantic Coastal Plain (Duffy and Whittecar 1991; Whittecar and Duffy 2000; Southworth et al. 2001). The Cretaceous Potomac Formation is a very thick unit of eroded material. The amount of erosion inferred from the now- exposed metamorphic rocks is immense. Many of the rocks exposed at the surface must have been at least 20 km (~10 miles) below the surface prior to regional uplift and erosion. The erosion continues today: the Potomac, Rappahannock, Rapidan, Monocacy, and Shenandoah Rivers, and their tributaries strip Coastal Plain sediments, lower the mountains, and deposit alluvial terraces, creating the present landscape.

Since the breakup of Pangaea and the uplift of the Appalachian Mountains, the North American plate has continued to drift toward the west. The isostatic adjustments that uplifted the continent after the Alleghenian Orogeny continued at a subdued rate throughout the Cenozoic Period (Harris et al. 1997).

The landscape and geomorphology of the greater Potomac River valley are the result of erosion and deposition from about the mid- Cenozoic Period to the present, or at least the last 5 million years. The Potomac, flowing southeast, cuts obliquely across north- trending geologic units. Following the trend of joints and other fractures, the river flows straight through Mather Gorge. There is little to no evidence that the Potomac river migrated laterally across a broad, relatively flat region. The river apparently cut downward through very old, resistant rocks, overprinting its early course (Southworth et al. 2001).

The distribution of flood- plain alluvium and ancient fluvial terraces of the regional rivers and adjacent tributaries records the historical development of both drainage systems. At least six different terrace levels are identifiable in the Wolf Trap National Park for the Performing Arts area. The oldest of these is located on the crest of Glade Hill in nearby Great Falls Park. Here the Potomac river cut though bedrock and left deposits of large quartzite and diabase boulders. In creating these terraces, the river left behind islands, islets, pinnacles, oxbows, shoestring canals, potholes, and plunge pools—all erosional features that dot the landscape along the Potomac River today (Southworth et al. 2001).

Although glaciers from the Pleistocene Ice Ages never reached the central Maryland–Virginia area (the southern terminus was in northeastern Pennsylvania), the colder climates of the ice ages played a role in the formation of the landscape at Wolf Trap. The periglacial conditions that must have existed near the glaciers intensified weathering and other erosional processes (Harris et al. 1997). The landforms and deposits are probably late Tertiary to Quaternary in age when a wetter climate, sparse vegetation, and frozen ground caused increased precipitation to run into the ancestral river channels, enhancing downcutting and erosion by waterways (Means 1995; Zen 1997a and 1997b).

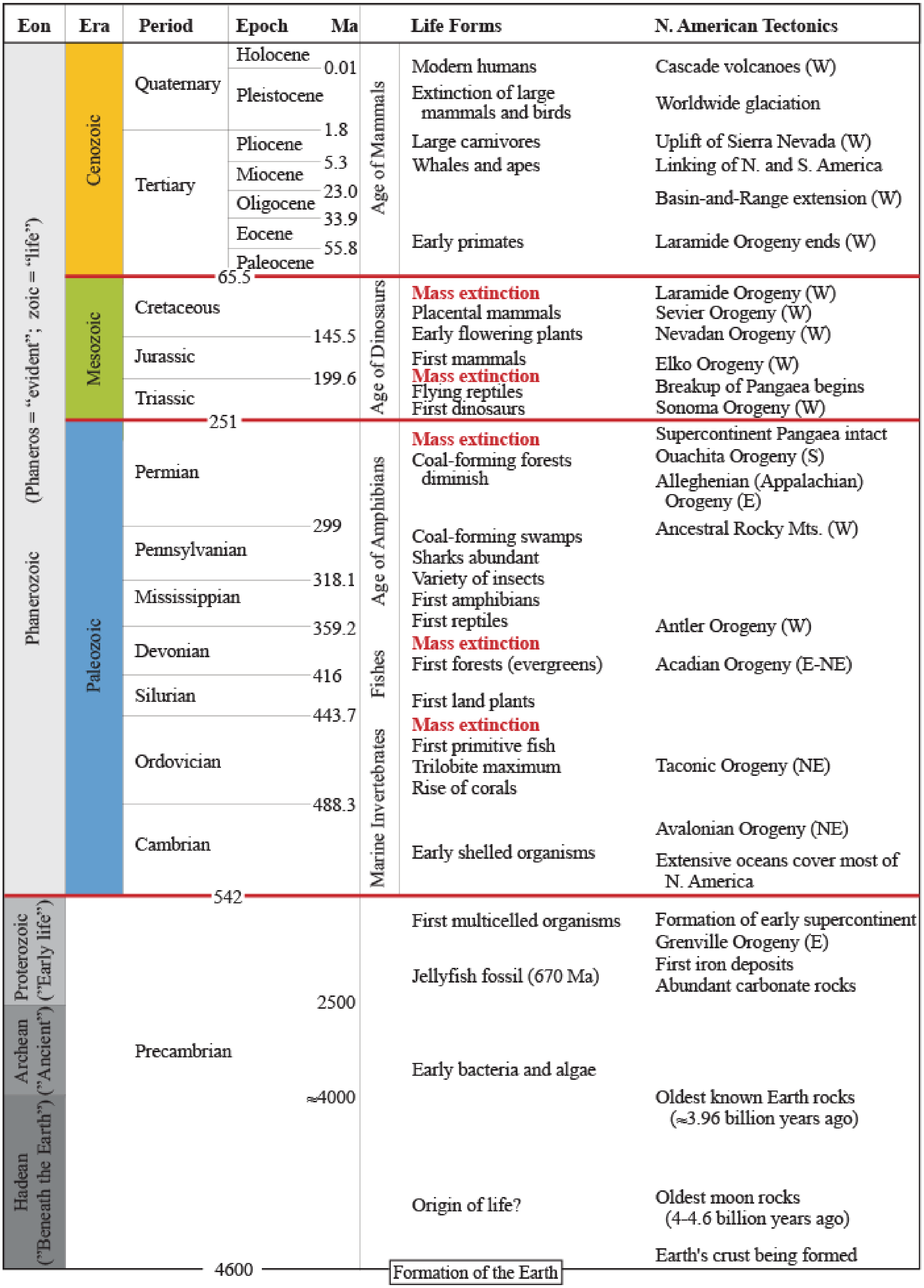

Figure 6: Geologic time scale; modified from the U.S. Geological Survey and International Commission on Stratigraphy. Red lines indicate major unconformities between eras. Included are major events in life history and tectonic events occurring on the North American continent. Absolute ages shown are in millions of years. W, S, E, NE (cardinal directions) refer to parts of the North American continent.

Eon	Era	Period	Epoch	Events
Phanerozoic	Cenozoic	Quaternary	Holocene	18 ka: Chesapeake Bay forms, shorelines evolve
			Pleistocene	Dramatic climate oscillations, rise and fall of sea level cutting scarps along major rivers
		Tertiary	Pliocene	Marine sedimentation
			Miocene	Chesapeake group, erosional interval
			Oligocene	Erosional interval
			Eocene	35.7 Ma: Chesapeake Bay Impact Structure
			Paleocene	Erosional interval
	Mesozoic	Cretaceous		Shallow sea covers eastern Virginia
		Jurassic		Atlantic Ocean opens, east-flowing rivers develop
		Triassic		Atlantic rifting begins- Deposition of sediments in rift basins
	Paleozoic	Permian		325-265 Ma: ALLEGHENIAN OROGENY
		Pennsylvanian		Coals deposited in coastal swamps 300 Ma: Petersburg granite emplaced
		Mississippian		Passive margin sedimentation
		Devonian		360 Ma: ACADIAN OROGENY
		Silurian		Taconic highlands eroded
		Ordovician		440-420 Ma: TACONIC OROGENY
		Cambrian		Carbonate deposition on passive margin
Proterozoic	Neoproterozoic			600-550 Ma: Late phase of Iapetan rifting 750-700 Ma: Early phase of Iapetan rifting
	Mesoproterozoic			1100-950 Ma: GRENVILLIAN OROGENY
	Paleoproterozoic			

Figure 7: Geologic time scale specific to Virginia. Dates are approximate. Modified from Bailey and Roberts (1997-2003).

Glossary

This glossary contains brief definitions of technical geologic terms used in this report. Not all geologic terms used are referenced. For more detailed definitions or to find terms not listed here please visit: http://wrgis.wr.usgs.gov/docs/parks/misc/glossarya.html.

alluvial fan. A fan- shaped deposit of sediment that accumulates where a high- gradient stream flows out of a mountain front into an area of lesser gradient such as a valley.

alluvium. Stream- deposited sediment that is generally rounded, sorted, and stratified.

aquifer. Body of rock or sediment that is sufficiently porous, permeable, and saturated to be useful as a source of water.

anticline. A generally convex fold with older rock in the center and progressively younger rock toward the edges.

anticlinorium. A regional anticlinal structure composed of lesser folds.

ash (volcanic). Fine pyroclastic material ejected from a volcano.

barrier island. A long, low, narrow island formed by a ridge of sand that parallels the coast.

base flow. Streamflow supported by groundwater flow from adjacent rock, sediment, or soil.

basement. The undifferentiated rocks, commonly igneous and metamorphic, that underlie identified rock units.

basin (structural). A doubly plunging syncline in which rocks dip inward from all sides.

basin (sedimentary). Any depression, from continental to local scale, into which sediments are deposited.

bed. The smallest sedimentary strata unit, commonly ranging in thickness from 1 centimeter to a meter or two and distinguishable from beds above and below.

bedding. Depositional layering or stratification of sediments.

bedrock geology. The geology of underlying solid rock as it would appear with the sediment, soil, and vegetative cover stripped away.

calcareous. A rock or sediment containing calcium carbonate.

chemical weathering. The dissolution or chemical breakdown of minerals at Earth's surface via reaction with water, air, or dissolved substances.

clastic. Rock or sediment made of fragments of preexisting rocks.

clay. Clay minerals or sedimentary fragments the size of clay minerals (grain size <0.002 mm).

conglomerate. A coarse- grained sedimentary rock with clasts larger than 2 mm in a fine- grained matrix.

continental crust. The type of crustal rocks underlying the continents and continental shelves; having a thickness of 25–60 km (16–37 mi) and a density of approximately 2.7 grams per cubic centimeter.

continental shelf. The shallowly submerged portion of a continental margin extending from the shoreline to the continental slope with water depths of less than 200 m (656 ft).

craton. The relatively old and geologically stable interior of a continent (also see continental shield).

crust. The outermost compositional shell of Earth, 10–40 km (6–25 mi) thick, consisting predominantly of relatively low density silicate minerals (also see oceanic crust and continental crust).

crystalline. Describes the structure of a regular, orderly, repeating geometric arrangement of atoms.

deformation. A general term for the process of faulting, folding, shearing, extension, or compression of rocks as a result of various Earth forces.

delta. A sediment wedge deposited at a stream's mouth where it flows into a lake or sea.

dike. A tabular, discordant igneous intrusion.

dip. The angle between a structural surface and a horizontal reference plane measured normal to their line of intersection.

ephemeral stream. A stream that flows only in direct response to precipitation.

extrusive. Of or pertaining to the eruption of igneous material onto the surface of Earth.

fan delta. An alluvial fan that builds into a standing body of water. The landform differs from a delta in that a fan delta is next to a highland and typically forms at an active margin.

fault. A subplanar break in rock along which relative movement occurs between the two sides.

formation. Fundamental rock- stratigraphic unit that is mappable and lithologically distinct from adjoining strata and has definable upper and lower contacts.

fracture. Irregular breakage of a mineral; also any break in a rock (for example, crack, joint, fault).

graben. A down- dropped structural block bounded by steeply dipping normal faults.

igneous. Refers to a rock or mineral that originated from molten material; one of the three main classes or rocks: igneous, metamorphic, and sedimentary.

intrusion. A body of igneous rock that invades older rock. The invading rock may be a plastic solid or magma that pushes its way into the older rock.

isostasy. The process by which the crust "floats" at an elevation compatible with the density and thickness of the crustal rocks relative to underlying mantle.

joint. A semi- planar break in rock without relative movement of rocks on either side of the fracture surface.

karst topography. Topography characterized by abundant sinkholes and caverns formed by the dissolution of calcareous rocks.

lacustrine. Pertaining to, produced by, or inhabiting a lake or lakes.

landslide. Any process or landform resulting from rapid mass movement.

lava. Magma that has been extruded out onto Earth's surface, both molten and solidified.

mafic. Refers to a rock, magma, or mineral rich in magnesium and iron.

magma. Molten rock generated within Earth that is the parent of igneous rocks.

mélange. A body of rock that is mostly unstratified and characterized by rock fragments of all sizes embedded in matrix of finer- grained fragments.

member. A lithostratigraphic unit with definable contacts that subdivides a formation.

metamorphic. Pertaining to the process of metamorphism or to its results.

metamorphism. Literally, "change in form." Metamorphism occurs in rocks with mineral alteration, genesis, and (or) recrystallization from increased heat and pressure.

migmatite. Literally, "mixed rock" with both igneous and metamorphic characteristics due to partial melting during metamorphism.

normal fault. A dip- slip fault in which the hanging wall moves down relative to the footwall.

oceanic crust. Earth's crust formed at spreading ridges that underlies the ocean basins. Oceanic crust is 6–7 km (3–4 mi) thick and generally of basaltic composition.

orogeny. A mountain- building event, particularly a well-recognized event in the geologic past. (The Laramide orogeny is one well- recognized example.)

outcrop. Any part of a rock mass or formation that is exposed or "crops out" at Earth's surface.

overbank deposits. Alluvium deposited outside a stream channel during flooding.

paleontology. The study of the life and chronology of Earth's geologic past based on the phylogeny of fossil organisms.

Pangaea. A theoretical, single supercontinent that existed during the Permian and Triassic.

pebble. Generally, small, rounded rock particles from 4 to 64 mm in diameter.

plateau. A broad, flat- topped topographic high of great extent and elevation above the surrounding plains, canyons, or valleys (both land and marine landforms).

pluton. A body of intrusive igneous rock.

plutonic. Describes igneous rock intruded and crystallized at some depth in Earth.

porosity. The proportion of void space (cracks, interstices) in a volume of a rock or sediment.

recharge. Infiltration processes that replenish ground water.

sandstone. A sedimentary rock of predominantly sand-sized grains, especially quartz.

scarp. A steep cliff or topographic step resulting from vertical displacement on a fault or by mass movement.

sediment. An eroded and deposited, unconsolidated accumulation of lithic and mineral fragments.

sedimentary rock. A consolidated and lithified rock consisting of detrital and (or) chemical sediment(s).

shale. A clastic sedimentary rock made of clay- sized particles that exhibit parallel splitting properties.

sill. A tabular, igneous intrusion that is concordant with the country rock.

silt. Clastic sedimentary material intermediate in size between very fine sand and coarse clay (1/256- 1/16 mm).

siltstone. A variably lithified sedimentary rock with silt-sized grains.

slump. A generally large, coherent mass movement with a concave- up failure surface and subsequent backward rotation relative to the slope.

soil. Surface accumulation of weathered rock and organic matter capable of supporting plant growth and often overlying the parent rock from which it formed.

strata. Tabular or sheetlike masses or distinct layers (as, of rock).

stratigraphy. The geologic study of the origin, occurrence, distribution, classification, correlation, and age of rock layers, especially sedimentary rocks.

strike. The compass direction of the line of intersection that an inclined surface makes with a horizontal plane.

subduction. The process by which one crustal plate descends beneath another.

suture. The linear zone where two continental landmasses become joined due to obduction.

syncline. A fold generally convex upward wit hyiuner rock in the center and progressively older rock toward the edges.

synclinorium. A regional synclinal structure composed of lesser folds.

tectonic. Relating to large- scale movement and deformation of Earth's crust.

tectonics. The geologic study of the broad structural architecture and deformational processes of the lithosphere and aesthenosphere (a main focus of structural geology).

terraces (stream). Step- like benches surrounding the present flood plain of a stream due to dissection of previous flood plain(s), stream bed(s), and (or) valley floor(s).

thrust fault. A contractional, dip- slip fault with a shallowly dipping fault surface (<45°) where the hanging wall moves up and over relative to the footwall.

topography. The general morphology of Earth's surface including relief and location of natural and anthropogenic features.

trend. The direction or azimuth of elongation of a linear geologic feature.

unconformity. A surface within sedimentary strata that marks a prolonged period of nondeposition or erosion.

uplift. A structurally high area in Earth's crust, produced by movement that raises the rocks.

water table. The upper surface of the saturated (phreatic) zone.

weathering. The set of physical, chemical, and biological processes by which rock is broken down in place.

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Appendix A: Geologic Map Graphic

The following page is a preview or snapshot of the geologic map for Wolf Trap National Park for the Performing Arts. For a poster- size PDF of this map or for digital geologic map data, please see the included CD or visit the Geologic Resource Evaluation publications Web page (http://www2.nature.nps.gov/geology/inventory/gre_publications).

Appendix B: Scoping Summary

The following excerpts are from the GRE scoping summary for Wolf Trap National Park for the Performing Arts. The scoping meeting was on April 30–May 2, 2001; therefore, the contact information and Web addresses referred to in this appendix may be outdated. Please contact the Geologic Resources Division for current information.

Executive Summary

Geologic Resource Evaluation (GRE) workshops were held for National Park Service (NPS) Units in the National Capital Region (NCR) on April 30–May 2, 2001. The purpose was to view and discuss the park's geologic resources, to address the status of geologic mapping for compiling both paper and digital maps, and to assess resource management issues and needs. Cooperators from the NPS Geologic Resources Division (GRD), Natural Resources Information Division (NRID), individual NPS units in the region, and the U.S. Geological Survey (USGS) were present for the workshop.

This meeting involved half- day field trips to view the geology of Catoctin Mountain Park, Harpers Ferry NHP, Prince William Forest Park, and Great Falls Park, as well as another full- day scoping session to present overviews of the NPS Inventory and Monitoring (I&M) program, the GRD, and the ongoing GRE. Round- table discussions involving geologic issues for all parks in the National Capital Region included the status of geologic mapping efforts, interpretation, paleontologic resources, sources of available data, and action items generated from this meeting.

Geologic Mapping

Existing Geologic Maps and Publications

The index of published geologic maps is a useful reference for the NCR. However, some of these maps are dated and in need of refinement; in other places, no existing large- scale coverage is available. Through their project to map the Baltimore- Washington, D.C., area at 1:100,000 scale, the USGS learned that modern, large- scale geologic mapping of the NCR NPS areas would be beneficial to NPS resource management.

The USGS therefore proposed to re- map the NCR at large scale (1:24,000 or greater) accompanied by digital geologic databases. Scott Southworth (USGS- Reston, VA) is the project leader and main contact. The original PMIS (Project Management Information Systems) statement is available on the NPS intranet (PMIS number 60900).

Desired Enhancements in the Geologic Maps for NCR Parks

To facilitate the geologic mapping, Scott Southworth would like to obtain better topographic coverage for each of the NCR units. Tammy Stidham knows that some of these coverages are already available and will supply them to Scott and the USGS. In general, anything in Washington, D.C., proper has 1- meter topographic coverage and Maryland's Prince George's County has 1:24,000 coverage.

Notes on Wolf Trap National Park for the Performing Arts

Wolf Trap Farm (WOTR) has 1:24,000- scale topographic coverage.

Digital Geologic Map Coverage

The USGS will supply digital geology in ArcInfo format for all NCR parks. GRE staff will add the Windows help file and NPS theme manager capability to the digital geology and will supply to the region for distribution to each NCR park.

Other Desired Data Sets for NCR

Soils

Pete Biggam (GRD Soil Scientist) supplied the following information about park soils: National Capital Parks—Central is covered by the "District of Columbia" Soil Survey (State Soil Survey Area ID MD099). It has been mapped, and is currently being refined to match new imagery. An interim digital product is available via NRCS, but the "final certified" data set most likely will not be available until FY03. National Capital Parks—East is covered by portions of three soil survey areas: "District of Columbia" (MD099), "Charles County, Maryland" (MD017), and "Prince George's County, Maryland" (MD033). Both Charles and Prince George's Counties are currently being updated, with Charles County scheduled to be available sometime in 2002, and Prince George's County sometime in 2003.

Paleontology

- Greg McDonald (GRD Paleontologist) recommends a systematic paleontological inventory for the NCR, describing the known resources in all parks, with suggestions on how to best manage these resources. His current database shows parks containing paleontological resources in NACE and NCR.

Geologic Report

A "stand- alone" encompassing report on each park's geology is a major focus of the GRE. The proposed USGS mapping of the NCR will include a report summarizing the major geologic features of each park.

Participants recommended that a regional physiographic report be completed for the entire NCR after the individual reports are finished.

List of Attendees for NPS National Capital Region Workshop

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Appendix C: Report of the NPS Monitoring Workshop

Planning for the Future in the National Capital Network

The following excerpts are from the National Capital Network monitoring workshop held on July 9- 11, 2002, in Shepherdstown, West Virginia. This appendix includes pages 29- 44 of the original workshop report; their content is directly relevant to the geologic resource evaluation of Wolf Trap National Park for the Performing Arts.

B. Geology Workgroup

Purpose:
Continue the development of vital signs indicators for geologic resources in the National Capital Region of the National Park Service to provide essential information needed to preserve and enhance the region's most important geologic resources.

Outcomes:
1) Complete the geology table from previous meetings, allowing time to clarify items already in the table and identify additional information gaps

2) Prioritize items in the geology table for future monitoring efforts

3) Develop monitoring objectives for high priority threats in the geology table.
4) Develop a list of potential protocols that would meet the above monitoring objectives from the geology table.

Overview
This breakout session began by reviewing the conceptual model describing the geologic resources developed by the geology workgroup of the SAC including (1) resource components, (2) stressors to those resources, (3) sources of stressors, (4) ecological effects, and (5) potential vital signs monitoring indicators. Terminology was clarified, existing information was edited, and new information was added. The results of this discussion are captured in Table 4 below.

One point that was not captured in Table 4 (but which should be noted) is that the geology workgroup examined soil from an agricultural perspective, rather than from an engineering perspective. In addition, several people in the group commented that geology is an integrative, long- term perspective for monitoring, although there are both short- and long- term indicators that may be used to examine threats to the geological resources in the NCN.

Other topics of discussion during the morning session were urban soils and "engineered or created landscapes". Urban soils are generally horticultural in context, some of which may be "engineered" but, by far, most urban soils are not. Urban soils tend to be non- agricultural or non- forest situations where man has, to one degree or another, manipulated the landscape such that the natural soil regime no longer exists. In most cases, soil structure has been lost or redeveloped. In many cases, urban soils were composed from subsurface soils and, therefore, nothing resembling an "A" horizon exists.

Urban soils are often compacted, resulting in high bulk densities, and, as a result, have reduced oxygen content (e.g. trails, campsites, etc.). In addition, these soils are poorly drained, low in organic matter, retain little moisture, may be disconnected from the water table or capillary water, could be contaminated or have considerable "artifacts" (ash, glass, etc.), and are often depauperate in microfauna (bacteria, fungi) and macrofauna such as worms (even if most worms are non- native). Thus, many of the highly important landscape areas of National Capital Region, including the National Mall, battlefield cemeteries, visitor centers, picnic areas, trails, tow paths, etc., are places where manipulated soils need to be understood from their creation, through use and then management.

In addition, created landscapes were identified as one of the more unique, geological components of the National Capital Network (and especially, Washington DC), and for which the group felt that very little information currently was available. On one hand, these changed environments could lead to increased diversity - due to the potentially more- complex mosaic of soils and resulting vegetation communities. On the other hand, these landscapes are commonly affected by human manipulation, horticultural and agricultural practices, and urban landscaping efforts, all of which tend to lower biodiversity and lead to an increased occurrence of exotic species.

Several potential research topics were also discussed: historical records of floods, sedimentation, and land use in the region. Historical records of floods should be relatively easy to find for the National Capital Region. For example, Metro records and historical documents may provide an indication of historic structures affected by flooding on a sequential basis. In addition, Jim Patterson (NPS - retired) may have a lot of background information on NCR parks.

Sediment coring may also be used to provide a historical perspective on sediment "cycling" throughout the history of this region. The use of aerial photos, as available, may provide the necessary data to examine land use change over time, changes in stream morphology over time, and shoreline change over time.

Finally, through the use of newer technologies such as LIDAR and GPS, it is possible to examine changes in topography and geomorphology, at a fine scale, which is especially important in the Piedmont and Coastal Plain areas of the National Capital Region that have little or no topographic relief (e.g. Dyke Marsh).

In the afternoon session, the workgroup focused upon ways to condense the list of 30 threats to geological resources into a more manageable size (Table 5). This proved to be a difficult task due to the varied nature of some of the components in Table 4. The first two categories, (1) nutrients and contaminants and (2) erosion and sedimentation, were natural groupings of many of the entries in Table 4. The remaining components of Table 4 were more difficult to categorize because they did not fit nicely into a single group heading. However, the workgroup was finally able to group the components into the following subject headings: nutrient and contaminant cycling, sediment cycling, engineered lands and urban soils, shoreline change, geo- hazards, human influences within the park boundary, and human influences outside the park boundary. The group next began to prioritize these subject areas, but decided that some of these categories were too contrived, or overlapped too much, to be separated out in this way.

The final geology working group session was held on Thursday morning. The group decided to continue through the prioritization process by beginning with the categories that they were satisfied with - nutrient and contaminant cycling, and sediment cycling. For these two groupings, the group suggested established protocols for monitoring, wrote monitoring goals and objectives and identified potential collaborators. Once this analysis was completed for nutrient/contaminant and sediment cycling, the discussion continued for engineered lands and urban soils, shoreline change and geo- hazards.

The categories of human influences within the park boundary and human influences outside the park boundary were decided to be too broad and thus were eliminated from Table 4.
Categories were then ranked by considering the significance of the threat to the parks in the NCN, which included the following factors: amount of area affected by the threat, intensity of the threat to the resource, urgency of the threat to the resource, monitoring feasibility, and cost of monitoring.

By the end of the morning session, the group had decided upon the following categories, in priority order: nutrient and contaminant cycling, sedimentation and erosion, lack of understanding of engineered lands, shoreline change and geo- hazards. The workgroup then went back through Table 4 to assign all 30 elements to one (or more) of these specific groupings.

In addition to the work above, the workgroup noted information needs and studies of interest throughout the discussion. These are summarized below.

Information Needs:

A more recent and complete soils map for the region is needed.

Inventory information regarding land changes and the creation of lands for baseline data as well as how these lands change towards equilibrium is needed.

Are locations of air quality monitoring stations that also capture atmospheric deposition known? They need to be checked at the National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu) or discussed with the air workgroup.

What about non- point source pollution monitoring in the region?

Is anyone considering the effects of acid rain on monuments in the region? There was, at one time, a long- term monitoring project regarding this process (in DC)?

Has anyone examined the flood and floodplain history of this area?

Previous studies of interest in NCR:

There were studies at 4- Mile Run beginning in the 1950's (pre- urbanization) to look at or capture the effects of urbanization.

Jeff Houser (Oak Ridge) has looked at the effects of sedimentation on streams and stream biota.

Personnel Involved:

Facilitators: Christina Wright, NPS – NCN I & M Program and Dale Nisbet, NPS – HAFE
Participants: Joe Calzarette, Michelle Clements, Sid Covington, Dick Hammerschlag, Bob Higgins, Wright Horton, Lindsay McClelland, Wayne Newell, Scott Southworth, L. K. Thomas, and Ed Wenschhof.

Table 4. Revised conceptual model for geological resources in the NCN.

Resource Component	Stressor	Sources	Ecological Effects	Priority of Threat to Resource	Grouping used in priority table	Indicator/ Vital Sign	Protocol	Monitoring Goal	Potential contacts or collaborators
Soil	Pesticide loading	Agricultural, residential, and commercial use	Accumulation of pesticides that adhere to soil particles, causing changes to or the elimination of non- target soil fauna populations	High	1	Test soils and sediment for suite of pesticides commonly used in local area	Lithogeochemical studies (USGS), mass balance or input/output approach	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	Owen Bricker, Nancy Simon, Wayne Newell, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA, USGS - NAWQA
Soil/Bedrock	Nutrient loading	Agricultural, residential and commercial use	Acidification of the soil, reduction of soil organic matter, change in soil fertility status	High	1	Soil pH, soil N and P status, soil organic matter levels	Lithogeochemical studies (USGS), mass balance or input/output approach	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	Owen Bricker, Nancy Simon, Wayne Newell, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA, USGS - NAWQA
Soil/Bedrock	Change in pH, loss of buffering capacity	Acid rain, atmospheric deposition	Change in vegetation types, mycorrhiza and other soil flora, fauna	Unknown	1	Soil pH, acid neutralizing capacity (ANC)	Lithogeochemical studies (USGS), mass balance or input/output approach. Mass flow/hydrologic modeling.	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	Owen Bricker, Nancy Simon, Wayne Newell, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA, USGS - NAWQA
Soil	Temperature Change	Climate change	Changes in soil micro- climate	Unknown, locally high		Soil temperature/moisture regime, changes in soil flora, fauna and mycorrhiza suite	Soil temperature and moisture monitoring. Soil organism analysis.		
Soil/Surficial Factors	Clearing of land	Soil surface exposure, development, agriculture, zoning laws (local and county governments)	Loss of soil surface cover, increased soil surface and groundwater temperatures	High	2 and 3	Soil and groundwater temperature/moisture regime. Change in vegetation community. Land use change.	Measurement of soil surface and groundwater temperature, monitoring of bare soils in region. Land use change analysis, vegetation community analysis.	Use survey and analysis methods to evaulate changes in topography, sediment loading and water flow rates.	Rebecca Beavers (NPS - GRD), Wayne Newell, Nancy Simon, Pete Chirico (USGS - Reston), EPA - Office of Water and ORD, USGS - NAWQA, Loren Setlaw (?), Doug Curtis (NPS - CUE), Don Weeks (NPS - Denver)

Resource Component	Stressor	Sources	Ecological Effects	Priority of Threat to Resource	Grouping used in priority table	Indicator/ Vital Sign	Protocol	Monitoring Goal	Potential contacts or collaborators
Soil	Erosion	Development, land clearing, increasing impervious surface	Increased siltation, reduced productivity/health/abundance of soil, plants, and aquatic organisms	High	2 and 4	Sediment loading, increased sedimentation and changes in sedimentation patterns, land use change, change in topography, shoreline change, change in wetland extent and condition.	Shoreline change/Wetland extent - aerial photo analysis. Change in topography - LIDAR, GPS. Changes in sedimentation - bedload analysis, storm water event sampling, total suspended solids, light penetration in water column. Condition of wetland - changes in wetland plant species, multiband aerial photography.	Use survey and analysis methods to evaulate changes in topography, sediment loading and water flow rates.	Rebecca Beavers (NPS - GRD), Wayne Newell, Nancy Simon, Pete Chirico (USGS - Reston), EPA - Office of Water and ORD, USGS - NAWQA, Loren Setlaw (?), Doug Curtis (NPS - CUE), Don Weeks (NPS - Denver)
Soil/Surficial Factors	Erosion	Development	Change in "normal" sedimentation sequence and composition	Unknown, low	2 and 4	Increased deposition, change in scouring and deposition patterns, change in hydrologic flow regimes.	See above protocols. Also, analysis of sediment cores, including an analysis of historical sediment records.	Use survey and analysis methods to evaulate changes in topography, sediment loading and water flow rates.	Rebecca Beavers (NPS - GRD), Wayne Newell, Nancy Simon, Pete Chirico (USGS - Reston), EPA - Office of Water and ORD, USGS - NAWQA, Loren Setlaw (?), Doug Curtis (NPS - CUE), Don Weeks (NPS - Denver)
Soil	Change in vegetation /exotics	Development, nursery use of exotics	Change in soil organic matter composition, changes in soil flora and fauna, pH, nitrification rates	Unknown		Exotic species monitoring and control measures, soil chemistry, soil organic matter levels, soil pH, soil nitrification rates			
Soil, creation of new soils	Fill dirt: complete changes in soil physical and chemical composition resulting from filling in land areas with soil from another location (esp. DC)	Landfills, abandoned mines, land engineering	Changed, destroyed, or new soil profile, change in chemical composition of soil, introduction of toxics, introduction of impervious structures into soil profile, compaction. Resultant changes to biodiversity and vegetation communities. Changes to hydrologic cycle.	High - esp. urban	1 and 3	Assessment and description of soil profile, change in subsurface temperatures, change in land surface elevation profile, movement of physical debris from land, soil compaction, change in biodiversity of flora and fauna	Assessment and description of soil profile, surface and ground water monitoring (lithogeochemical studies), bulk density, porosity or other soil compaction measures.	To understand the functioning and components of engineered landscapes (components - landfills, engineered soils, etc.)	USDA - NRCS, Dick Hammerschlag (USGS - Patauxent), Wright Horton (USGS - Reston). Also see contacts for nutrient and sediment cycling.

Resource Component	Stressor	Sources	Ecological Effects	Priority of Threat to Resource	Grouping used in priority table	Indicator/ Vital Sign	Protocol	Monitoring Goal	Potential contacts or collaborators
Soil	Compaction	Visitor Use	Changes in vegetation survival, changes in soil physical properties, creation of soil crusts (an impervious surface).	Urban, locally - high	1 and 3	Monitor soil compaction, bulk density, porosity, or other soil compaction measures. Formation of soil crusts.	Soil coring, bulk density, porosity or other soil compaction measures.	To understand the effects of visitor use upon the soil profile - includes social and official trails.	
Soil	Impervious surfaces	Paving, walls, armored banks	Scouring, cutting/changing shoreline, flooding,	High	1 and 3	Increased velocity of storm water flow, land use change	Storm water event sampling, aerial photos to examine land use change.	To understand the effects of increasing impervious surfaces in the watershed upon hydrology.	Pat Bradley - EPA, USGS - NAWQA, EPA - Office of Water
Unique soils: calcareous and serpentine soils	Lack of information for these soils and soil in general	Lack of information for these soils and soil in general	Potential for damage to unknown/unmapped resource	unknown	1	Soils inventory work necessary.	Complete, up- to-date, high resolution soil maps	N/A	Pete Biggam - NPS, USDA - NRCS
Groundwater	Consumption of groundwater in excess of replenishment	Human, agricultural, residential, commercial use and domestic animal use	Reduced groundwater quantity, and quality. Loss of springs and seeps, wetland loss, changed of soil saturation zones. Change in drinking water quality and quantity.	High	1 and 2	Changes in groundwater table, Changes or loss of springs and seeps, change in extent of wetlands, changes in soil moisture profile.	Survey of groundwater table and groundwater chemistry. Groundwater flow monitoring wells		
Groundwater	Introduction of toxics, acid drainage (natural and mining)	Landfills, abandoned mines, land engineering, bedrock.	Reduced groundwater quality	high	1	Change in groundwater quality, quantity, and temperature. Increased toxics in groundwater.	Groundwater monitoring wells in conjunction with lithogeochemical studies (USGS), Mass balance or input/output approach	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	Owen Bricker, Nancy Simon, Wayne Newell, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA, USGS - NAWQA
Groundwater	Physical Failure	Landfills, abandoned mines, land engineering	Change in subsurface water flow patterns, change in subsurface temperatures, introduction of contaminants	High	5	Groundwater monitoring wells (flow and mapping), subsurface temperature changes	Aerial photo mapping of areas with potential physical failures. Park staff observations of potential geo-hazard sites. Expert analysis of geo-hazard sites on a periodic basis.	To use observation and assessment to provide an early warning of physical failure in order to protect the resource, visitors, and park infrastructure.	John Pallister, Bula Gori, Gerry Wieczoff - USGS

Resource Component	Stressor	Sources	Ecological Effects	Priority of Threat to Resource	Grouping used in priority table	Indicator/ Vital Sign	Protocol	Monitoring Goal	Potential contacts or collaborators
Groundwater	Water bypasses the soil profile	Old - abandoned wells (farms)	Increased groundwater contamination with nutrients, pesticides and other chemicals	Unknown	1	Change in groundwater quality, increased toxics in groundwater.	Groundwater monitoring and monitoring of abandoned wells in conjunction with lithogeochemical studies (USGS), Mass balance or input/output approach. Abandoned wells need to be found and sealed to minimize contamination.	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	Owen Bricker, Nancy Simon, Wayne Newell, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA, USGS - NAWQA
Groundwater	Impervious Surfaces	Roads, buildings, infrastructure	Reduced water infiltration leading to reduced groundwater recharge, movement of water between watersheds	Medium	1 and 2	Map and monitor groundwater recharge areas, monitor groundwater table levels and chemistry, subsurface temperature monitoring.			
Exposed rock	Cutting the toe of slopes, over-steepened slopes, dipslopes	Development, roads, structures, trails, flooding, vegetation death (hemlock etc.), logging	Reduced slope stability	Low	5	Slope failure, reduced slope stability, movement of materials downslope, erosion, gully formation	Aerial photo mapping of areas with potential physical failures. Park staff observations of potential geo-hazard sites. Expert analysis of geo-hazard sites on a periodic basis. Monitoring for gulley formation or increasing erosion.	To use observation and assessment to provide an early warning of physical failure in order to protect the resource, visitors, and park infrastructure.	John Pallister, Bula Gori, Gerry Wieczoff - USGS. Also see personnel under erosion categories.
Karst	Toxics: pesticides, dumping, spills	Agriculture, septic systems, sewage, dumping, industry, spills	Rapid movement of contaminants to ground water, change in ground water chemistry and resulting in change in biology	High – locally	1	Subterranean invertebrates, ground water chemistry/ quality	Analysis of subterranean invertebrates. Lithogeochemical studies (USGS), Mass balance or input/output approach	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	Smithsonian Institute Invertebrate specialists. Owen Bricker, Nancy Simon, Wayne Newell, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA, USGS - NAWQA

Resource Component	Stressor	Sources	Ecological Effects	Priority of Threat to Resource	Grouping used in priority table	Indicator/ Vital Sign	Protocol	Monitoring Goal	Potential contacts or collaborators
Karst	Nutrient loading	Agriculture, septic systems, sewage, dumping, industry, spills	Rapid movement of nutrients to ground water resulting in change to ground water quality and change in biology	High – locally	1	Subterranean invertebrates, ground water nutrient content	Analysis of subterranean invertebrates. Lithogeochemical studies (USGS), Mass balance or input/output approach	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	Smithsonian Institute Invertebrate specialists. Owen Bricker, Nancy Simon, Wayne Newell, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA, USGS - NAWQA
Karst	Structural collapse, sinkholes	Inappropriate construction practices, dissolution in karst areas	Change in biology due to changes in air flow and temperature, volume and flow of water increased in areas dissolution of bedrock	High – locally	5	Change in sinkhole size, aerial photos to capture surface changes, subsurface temperature monitoring	Aerial photo mapping of areas with sinkholes. Park staff observations of potential geo-hazard sites. Expert analysis of geo-hazard sites on a periodic basis.	To use observation and assessment to provide an early warning of physical failure in order to protect the resource, visitors, and park infrastructure.	John Pallister, Bula Gori, Gerry Wieczoff - USGS
Surface water	Impervious surfaces	Infrastructure, development, residential and agricultural use, rip rap, armoring etc.	Increased storm water flow, increased erosion, changes in sedimentation, changes in stream morphology, increased exposure to nutrients/pesticides, change in hydrologic cycle effecting floodplains, and floodplain/riparian buffer capacity, change in base flow	High	1 and 2	Stream storm water flow, flood frequency, sedimentation load, stream morphology. Photo points. Storm event sampling, Mass flow/hydrologic modeling	Lithogeochemical studies (mass balance approach).Shoreline change/Wetland extent - aerial photo analysis. Change in topography - LIDAR, GPS. Changes in sedimentation - bedload analysis, storm water event sampling, total suspended solids, light penetration in water column. Condition of wetland - changes in wetland plant species, multiband aerial photography.	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem. Use survey and analysis methods to evaluate changes in topography, sediment loading and flow rates.	Rebecca Beavers (NPS - GRD), Owen Bricker, Nancy Simon, Wayne Newell, Pete Chirico, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA - Office of Water, USGS - NAWQA
Surface water	Pesticide loading	Agricultural, residential, and commercial use	Reduced water quality, fishery health, and aquatic invertebrate communities and populations	High	1	Test for suite of pesticides commonly used in local area.	Lithogeochemical studies (USGS), Mass balance or input/output approach	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	Owen Bricker, Nancy Simon, Wayne Newell, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA, USGS - NAWQA

Resource Component	Stressor	Sources	Ecological Effects	Priority of Threat to Resource	Grouping used in priority table	Indicator/ Vital Sign	Protocol	Monitoring Goal	Potential contacts or collaborators
Surface water	Nutrient loading	Agricultural, residential and commercial use	Reduced water quality, fishery health, and aquatic invertebrate communities and populations. Algal blooms, eutrophication	High	1	Soil water and stream levels of N and P. High algal growth, low light penetration	Lithogeochemical studies (USGS), Mass balance or input/output approach	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	Owen Bricker, Nancy Simon, Wayne Newell, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA, USGS - NAWQA
Coastal areas	Impervious surfaces	rip rap, armoring, coastal walls, dredging	Changes in water flow rates, unnatural erosion and deposition, changes in natural shoreline, changes in sedimentation, wetland flooding, changes in wetland extent.	High – locally	1 and 2	Sedimentation coring (deep cores - research, shallow cores - monitoring), mapping of shoreline change, use of Pope's Creek as a reference area	Using aerial photos or survey methods to map shoreline and shoreline change over time.	Use mapping or survey methods to track changes in shoreline and depositional patterns, over time.	NOAA (?)
Lakes, ponds, seeps, vernal pools	Nutrient loading	Agriculture, residential lawn care, vegetation change	Eutrophication, change in fauna (esp. herps), effect upon T&E species	Unknown	1	Size/volume, chemistry, and temperature of surface water component	Lithogeochemical studies (USGS), Mass balance or input/output approach	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	Owen Bricker, Nancy Simon, Wayne Newell, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA, USGS - NAWQA
Lakes, ponds, seeps, vernal pools	Pesticide loading	Agriculture, residential, and commercial use	Addition of herbicides and pesticides to surface water, change in fauna, effect upon T&E species	Unknown	1	Pesticide, herbicide content of surface water component	Lithogeochemical studies (USGS), Mass balance or input/output approach	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	Owen Bricker, Nancy Simon, Wayne Newell, Wright Horton, David Russ (USGS - Reston), Mark Nellis (USGS - Denver), USDA, EPA, USGS - NAWQA
Riparian areas, Wetlands	Change in soil surface elevation and horizontal dimensions	Land engineering resulting in changes to deposition and erosion, dredging, dumping, creation of impoundments and dams	Disruption to the wetland/riparian ecosystems, change in storm water flow rates, vegetation change, wildlife change, change in stream bed characteristics	High	4	High resolution riparian/ wetland elevation monitoring, vegetation monitoring, sediment budget, changes in size of wetland area	Changes in wetland extent - aerial photo analysis. Change in topography - LIDAR, GPS. Changes in sedimentation - bedload analysis, storm water event sampling, total suspended solids, light penetration in water column. Condition of wetland - changes in wetland plant species, multiband aerial photography.	Use survey and analysis methods to evaulate changes in topography, sediment loading and water flow rates.	Rebecca Beavers (NPS - GRD), Wayne Newell, Nancy Simon, Pete Chirico (USGS - Reston), Richard Lowrance (USDA/ARS), EPA - Office of Water and ORD, USGS - NAWQA, Loren Setlaw (?), Doug Curtis (NPS - CUE), Don Weeks (NPS - Denver)

Table 1. Priority threats, vital signs, and monitoring goals and objectives for geological resources in the NCN.

Threats (in priority order)	**Vital Sign**	**Monitoring Goal**	**Monitoring Objectives**
Nutrient and chemical contamination	Changes in soil and groundwater chemistry.	Use an input/output approach to understand nutrient and contaminant cycling in the ecosystem.	(1) Measuring nutrient inputs from sources pertinent to each park unit. (2) Measuring contaminant inputs from sources pertinent to each park unit. (3) Tie information from numbers 1 and 2 to the hydrologic cycle, flood history, flood effects, and flood impacts.
Erosion and sedimentation	Changes in topography, sediment loading and deposition, shoreline change, wetland extent and condition.	Use survey and analysis methods to evaluate changes in topography, sediment loading, and flow rates.	(1) Measure loss of soil, growth of gullies, changes in streambanks…. (2) Track sedimentation history, effects, and impacts (including streams and ponds, hillslopes and gullies).
Lack of understanding of urban soils and engineered lands	Compaction, runoff, chemical composition, soil profile and structure, biodiversity.	To understand the functioning and components of urban soils engineered landscapes and their effects upon resident biota. Components include: highly impacted soil (compaction in and around trails, visitor centers), landfills, engineered soil, etc.	(1) Measure changes to physical components of urban soils and engineered lands and correlate with changes in resident biota (and exotic species). (2) Measure contaminant outflow from landfills, abandoned mines, etc.
Shoreline change	Inundation of wetlands, erosion and sedimentation processes.	Use mapping or survey methods to track shoreline change and depositional patterns.	(1) Measure shoreline change using aerial photos, LIDAR and survey methodologies and correlate changes to development, when possible. (2) Use sediment coring and historical data to understand long- term flood histories.
Geo- hazard	Physical failure, rock falls, landslides, sinkhole collapse.	Use observation and assessment to provide an early warning of physical failure to protect the resource, visitors, and park infrastructure.	(1) Monitor areas of potential hazard due to unstable slopes, rockfalls, etc. (2) Monitor for changes in unstable engineered sites or areas that are geologically active (e.g. Potomac Gorge). (3) Document and monitor areas underlain by swelling clays.

Appendix D: Geoindicators Notes

NCR Geoindicators Meeting May 20, 2002

Attendees:

NPS
Christine Wright, Data Manager, CUE
Marcus Koenen, Monitoring Coord., CUE
Pat Toops, Nat. Res. Chief, NCR
Bob Higgins, GRD - Denver
Sid Covington, GRD - Denver
Lindsay McClelland, GRD - Washington
Rijk Morawe, Nat. Resources Mgt. Specialist, GEWA

USGS
Nancy Simon, WRD
Marty Gurtz, Water Quality Program
Bill Bartlett, Water Quality Program
Owen Bricker, WRD (Geochem./Hydrology)
Wayne Newell
Scott Southworth
Peter Chirico

Vital Signs Network - Marcus Koenen
1. National Capital Region (NCR) began monitoring about 3 years ago.
2. Planning process will help determine what the important issues are; what specific indicators need to be monitored.
3. Final plan should be completed by Spring 2004.

Geology Overview

by Scott Southworth

1. Antietam National Battlefield and Monocacy National Battlefield.
    a. Share similar geology.
    b. Underlain by carbonates; karst topography.
2. Catoctin Mountain Park.
    a. Quaternary alluvium.
    b. Debris flows.
    c. Few slope hazard issues.
    d. Completely clear- cut by mid- 30s.
3. Rock Creek; George Washington Mem. Parkway; Wolf Trap Farm; Prince William Forest.
    a. Share similar geology and issues.
    b. Similar land use, but different surfaces.
    c. Landscape has been extremely modified and altered (esp. Rock Creek).
4. Prince William Forest.
    a. Acid mine drainage.
    b. Heavily forested; highly altered.
5. General.
    a. Ground water is an issue in almost all the NCR parks.
    b. Data on river pollution should become available on a CD ROM.
    c. Need to look at processes along the strike of faults, esp. in Piedmont and Blue Ridge provinces.
    d. Potomac Conservancy Plan - developed by the NPCA; common link among geologic provinces.
    e. Lithochemical studies - study the path of nutrients through various rock lithologies (McClelland).
    f. Rates of erosion are increasing from the incising effects of runoff.

Soils

1. The chemistry of soils is based on the geology; how and from what rock type are the soils derived.
2. Look at the "geochemical landscape".
3. Soil studies are needed at Catoctin Mt.; can be used as an example.
4. Partnering needed with the Natural Resources Conservation Service (NRCS).
5. Biologists are most interested in soils developed from ultramafic rocks.
6. Need long- term monitoring:
    a. Atmospheric stations to see what is coming in from the air (for example, acid deposition).
    b. Streamflow site monitoring.

c. Suite of biological components to monitor change.
7. Need to monitor what comes into the system, what is in the system, and what leaves the system.

George Washington Birthplace (Nancy Simon)

1. Maybe less altered; looking at "natural" processes: sediment transport from pastures fertilized with sewage sludge from sewage treatment plants.
2. Compare with areas not using sludge, using GEWA as a reference site.
3. Very good watershed to study; use as a baseline (also Oxon Run estuary, rather than Anacostia).
4. Draw in surrounding people (landowners) to interpret study.
5. Arboretum - has funding been cut?
6. Need to look at:
    a. "Natural" (such as Catoctin) v. changing areas (such as George Washington Parkway).
    b. Parks with geologic similarities and compare with vegetation (Toops); similar vegetation areas may vary geologically along strike.
    c. A larger, more inclusive perspective - areas outside the parks that have similar characteristics.
    d. Water quality (w/NAQWA) and effects of urbanization.
    e. Certain indicator parks at different stages:
        (1) Unaltered ("natural").
        (2) Slightly or moderately altered.
        (3) Greatly altered.
        (4) Altered, but recovering.
    f. Historical forestation (or deforestation); example: conditions during the Civil War (Chirico).

Geoindicators Worksheet

1. Surface Water
    a. Stream channel morphology:
        (1) C & O Canal (no jurisdiction of channel).
        (2) Antietam Creek.
        (3) Catoctin Mt.
        (4) Manassas - Bull Run Creek.
        (5) Rock Creek - greatly affected by urbanization; removing barriers to herring spawning.
        (6) George Washington Parkway and Great Falls – urbanized.
    b. Need to look at tributaries as well as major streams.
    c. Human impacts on surface water flow (Chirico).
        (1) What was the topography prior to human impact? Some streams have been filled 20- 30 meters with coal ash, brick, dirt fill; Tiger Creek is now the Red Metro line.
        (2) What do we monitor from now on?
        (3) Streams have been converted to wastewater and stormwater discharges.
        (4) Some trend exists to "daylight" streams - reopening streams that were buried, exposing the stream bed down to the drainage pipes.
        (4) Much of the urbanized land that was cleared has been stripped and moved down into stream valleys; this can be studied by coring (Bricker).
        (5) There has been a flattening out of the topography by removing hills and filling in the streams; changes in slope affect channel morphology; between 1888 and today, the amount of material removed is equivalent to the material deposited by Mount St. Helens in 1980.
        (6) Surface streams have been converted to groundwater channels; comparisons of surface drainage from 1888 to 1999 shows very little similarity; difficult to compare.
        (7) Look at old studies and publications: Leopold, Walden, Hack. (Newell).
    d. Need better topography data:
        (1) Topographic data for Catoctin Mt. is very poor.
        (2) Counties are doing better work and producing better maps than the GS. Sometimes the data are available but not to the Federal agencies; may need to purchase.
    e. What kind of data is needed for streamflow? Not much baseline data; need cross sections; not much streamflow data in D.C. metro area; how important are streams to a particular unit?
    f. Maybe need to look at the geoindicator table as, for example, what factors affect stream morphology?
    g. Need "event sampling" - sample streams during flood or high water events (Simon).
    h. Streamflow is more than just monitoring; need index of hydrologic alteration (Nature Conservancy); how has streamflow changed? look at historical versus today's conditions; TNC has added predictability and looks at it slightly differently than the GS; need to look at historical data; in some cases, we have the information but no analysis of the data (Gurtz).

2. Sediment Influx

a. Oxon Run; GW Parkway below National AP (Dike Marsh); Anacostia; C&O Canal (effects of locks and channelization); Piscataway Creek (Newell).
b. What does park management want the parks to look like? Need to know where you want to go; for example, should we be looking at the morphology of Bull Run Creek at Manassas? (Toops)
c. Look at what will happen if we further alter a stream (Gurtz).

3. Wetlands

a. Not a major issue.
b. Anacostia has recreated/is recreating wetlands.
c. Some studies done by the D.C. Dept. of Health and USGS MD District.
d. NOAA studies mostly water quality.

4. Groundwater

a. Groundwater level:
(1) Level in Maryland is dropping, wells are running dry; vegetation is probably changing; moratorium on new home construction in Frederick Co., Md., due to low groundwater level.
(2) Drought and growth have made ground water a big issue; removal is outpacing recharge (surface water is still sufficient for now; Potomac is heavily used for water and for sewage, run-off and sewage treatment recharge).
(3) Maryland has a network of 17 monitoring wells.
b. Groundwater quality:
(1) Does the NPS need to drill monitoring wells to monitor level and quality and impact on biota (especially plants, amphibians)?
(2) Manassas, Antietam, Catoctin, and Anacostia all need monitoring wells (Newell and Chirico).
(3) Aquifers (except in the Coastal Plain) are fairly small and isolated in fault blocks, lithology, and fractures; no large aquifers like in the Midwest.

5. Karst

a. Karst topography at Antietam, C&O Canal, and Harpers Ferry.
b. Seeps and springs are important to some parks: C&O Canal has streams that flow into underground karst and seep out into the Potomac.
c. Southworth has done some mapping in the C&O Canal/Antietam area.
d. C&O has 8 abandoned mines and 14 caves; no active cave interpretation; some of the caves are open, but not a major resource to the park.
e. Problems with contamination from pesticides, fertilizers, sewage, run- off, others.

6. Hazards

a. Colluvial rock slides an issue at Harpers Ferry.

7. Relative Sea Level

a. Most shorelines are armored (see: Andy Miller, USGS, Rates of erosion around the Potomac area).
b. George Washington Birthplace (GEWA).
(1) Mouth of Popes Creek has an accreting delta derived from eroded material at GEWA.
(2) Cores from Popes Creek show agricultural influx from about 1650 on; can see effects of land clearing, tobacco farming, and other agricultural uses in cores.
(3) Need PMIS statement for coring.
c. Need to document changes in shoreline both historically and from recent events.
d. What are the impacts of armoring, and what would be the impacts of further armoring?
e. Piscataway Park - shoreline erosion.
f. Shorelines around the NCR coastal parks have been greatly altered.

8. Soils (Redux)

a. Soils are derived from a variety of basement rocks: limestones, saprolites, red shales, and quartzites.
b. Coastal Plain - stripped of sediment and soils since Colonial time (~1650); soil dumped into streams.
c. Beavers have become an important factor by retarding the loss of sediment.
d. Indicators: Change in acidity; Ca and Mg replaced by Al.
e. Monitor acid deposition (PMIS?); where?

Wolf Trap National Park for the Performing Arts

Geologic Resource Evaluation Report

Natural Resource Report NPS/NRPC/GRD/NRR—2008/041
NPS D-43, June 2008

National Park Service

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Natural Resource Stewardship and Science

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